11-22-00 A

Please type a plus sign (+) Inside this box ⊞

UTILITY PATENT APPLICATION TRANSMITTAL (Only for new nonprovisional applications under 37 C F R § 1 53(b))	Attorney Docket No.	107044-0002
	First Inventor or Application Identifier	William P. Acker et al.
	Title	FUEL CELL SYSTEM WITH ACTIVE METHANOL CONCENTRATION CONTROL
	Express Mail Label No.	EL705759021US

APPLICATION ELEMENTS
See MPEP chapter 600 concerning utility application contents

ADDRESS TO: Assistant Commissioner for Patents
Box Patent Application
Washington, DC 20231

1. ☒ *Fee Transmittal Form (e.g., PTO/SB/17)
(*Submit an original and a duplicate for fee processing*)
2. ☒ Specification [*Total Pages* 13]
(*preferred arrangement set forth below*)
- Descriptive title of the Invention
- Cross References to Related Applications
- Statement Regarding Fed sponsored R & D
- Reference to Microfiche Appendix
- Background of the Invention
- Brief Summary of the Invention
- Brief Description of the Drawings (*if filed*)
- Detailed Description
- Claim(s)
- Abstract of the Disclosure

3. ☒ Drawing(s) [*Total Sheets* 6]
4. Oath or Declaration [*Total Pages* 3]
a ☒ Newly executed (original copy)
b ☐ Copy from a prior application (37 C F R § 1 63(d))
(*for continuation/divisional with Box 17 completed*)
[Note Box 5 below]
DELETION OF INVENTOR(S)
☐ Signed statement attached deleting inventor(s) named in the prior application, see 37 C F R §§ 1 63(d)(2) and 1 33(b)
5. ☐ Incorporation By Reference (*useable if Box 4b is checked*)
The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered to be part of the disclosure of the accompanying application and is hereby incorporated by reference therein

6. ☐ Microfiche Computer Program (*Appendix*)
7. Nucleotide and/or Amino Acid Sequence Sequence Submission
((*if applicable, all necessary*)
a. ☐ Computer Readable Copy
b. ☐ Paper Copy (Identical to computer copy)
c. ☐ Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS
8. ☒ Assignment Papers (cover sheet & document(s))
9. ☐ 37 C.F.R.§3.73(b) Statement (*when there is an assignee*) ☒ Power of Attorney
10. ☐ English Translation Document (*if applicable*)
11. ☒ Information Disclosure Statement (IDS)/PTO-1449 ☒ Copies of IDS Citations
12. ☐ Preliminary Amendment
13. ☒ Return Receipt Postcard (MPEP 503) (*Should be specifically itemized*)
14. ☐ *Small Entity Statement(s) (*(PTO/SB/09-12)*) ☐ Statement filed in prior application, Status still proper and desired
15. ☐ Certified Copy of Priority Document(s) (*if foreign priority is claimed*)
16 ☐ Other:

*NOTE FOR ITEMS 1 & 14: IN ORDER TO BE ENTITLED TO PAY SMALL ENTITY FEES, A SMALL ENTITY STATEMENT IS REQUIRED (37 C. F. R. §1.27), EXCEPT IF ONE FILED IN A PRIOR APPLICATION IS RELIED UPON (37 C. F. R. § 1.28).

17. If a CONTINUING APPLICATION, *check appropriate box and supply the requisite information below and in a preliminary amendment*:
☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No.: /
Prior application Information: *Examiner* *Group/Art Unit:*

18. CORRESPONDENCE ADDRESS

☒ Customer Number or Bar Code Label (Insert Cus[illegible]) 24267 PATENT TRADEMARK OFFICE (abel here) or ☐ Correspondence address below

Name	Michael E. Attaya				
Address	Cesari and McKenna 88 Black Falcon Avenue				
City	Boston	State	MA	Zip Code	02210
Country	U. S. A.	Telephone	(617) 951-2500	Fax	(617) 951-3927

Name (*Print/Type*)	Michael E. Attaya	Registration No. (*Attorney/Agent*)	31,731
Signature	Michael E. Attaya	Date	November 21, 2000

Jc945 U.S. PTO 11/21/00
Jc914 U.S. PTO 09/717148 11/21/00
09717148 - 112100

FEE TRANSMITTAL

Patent fees are subject to annual revision on October 1.
These are the fees effective October 1, 1997.
Small Entity payments must be supported by a small entity statement, otherwise large entity fees must be paid. See Forms PTO/SB/09-12.
See 37 C.F.R. §§ 1.27 and 1.28.

TOTAL AMOUNT OF PAYMENT ($) 1,118

Complete If Known	
Application Number	Not Yet Assigned
Filing Date	November 21, 2000
First Named Inventor	William P. Acker et al.
Examiner Name	Not Yet Assigned
Group / Art Unit	Not Yet Assigned
Attorney Docket No.	107044-0002

METHOD OF PAYMENT (check one)

1. ☐ The Commissioner is hereby authorized to charge indicated fees and credit any over payments to:

Deposit Account Number: 03-1237

Deposit Account Name: Cesari and McKenna, LLP

☒ Charge Any Additional Fee Required Under 37 C.F.R. §§1 16 and 1.17 ☐ Charge the Issue Fee Set in 37 C.F R. §§1 18 at the Mailing of the Notice of Allowance

2. ☒ Payment Enclosed: ☒ Check ☐ Money Order ☐ Other

FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
101	710	201	35	Utility filing fee	710
106	320	206	160	Design filing fee	
107	490	207	245	Plant filing fee	
108	710	208	355	Reissue filing fee	
114	150	214	75	Provisional filing fee	
				SUBTOTAL (1)	($) 710

2. EXTRA CLAIM FEES

			Extra Claims		Fee from below	=	Fee Paid
Total Claims	36	- 20** =	16	×	18	=	288
Independent Claims	4	- 3** =	1	×	80	=	80
Multiple Dependent						=	0

**or number previously paid, if greater; For Reissues, see below

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
103	18	203	9	Claims in excess of 20
102	80	202	40	Independent claims in excess of 3
104	270	204	135	Multiple dependent claim, if not paid
109	80	209	40	**Reissue independent claims over original patent
110	18	210	9	**Reissue claims in excess of 20 and over original patent
				SUBTOTAL (2) ($) 368

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
105	130	205	65	Fee Surcharge - late filing fee or oath	
127	50	227	25	Surcharge - late provisional filing fee or cover sheet	
139	130	139	130	Non-English Specification	
147	2,520	147	2,520	For filing a request for reexamination	
112	920	112	920*	Requesting publication of SIR prior to Examiner action	
113	1,840	113	1,840*	Requesting publication of SIR after Examiner action	
115	110	215	55	Extension for reply within first month	
116	390	216	195	Extension for reply within second month	
117	890	217	445	Extension for reply within third month	
118	1,390	218	695	Extenstion for reply within fourth month	
128	1,890	128	945	Extension for reply within fifth month	
119	310	219	155	Notice of Appeal	
120	310	220	155	Filing a brief in support of an appeal	
121	270	221	135	Request for oral hearing	
138	1,510	138	1,510	Petition to institute a public use proceeding	
140	110	240	55	Petition to revive - unavoidable	
141	1,240	241	620	Petition to revive - unintentional	
142	1,240	242	620	Utility Issue fee (or reissue)	
143	440	243	220	Design Issue fee	
144	600	244	300	Plant Issue fee	
122	130	122	130	Petitions to the Commissioner	
123	50	123	50	Petitions related to provisional applications	
126	240	126	240	Submission of Information Disclosure Stmt	
581	40	581	40	Recording each patent assignment per property (times number of properties)	40
146	710	246	355	Filing a submission after final rejection (37 CFR 1.129(a))	
149	710	249	355	For each additional invention to be examined (37 CFR 1.129(b))	
				Other (specify)	
				Other fee (specify)	
				SUBTOTAL (3)	($) 40

*Reduced by Basic Filing Fee Paid

SUBMITTED BY				Complete (if applicable)	
Typed or Printed Name	Michael E. Attaya			Reg. Number	31,731
Signature	Michael E. Attaya	Date	November 21, 2000	Deposit Account User ID	

PATENT
107044-0002

UNITED STATES PATENT APPLICATION

of

William P. Acker

George C. McNamee

and

William W. Dailey

for a

FUEL CELL SYSTEM WITH ACTIVE METHANOL CONCENTRATION CONTROL

DO NOT ENTER

FUEL CELL SYSTEM WITH ACTIVE METHANOL CONCENTRATION CONTROL

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates generally to the field of fuel cells and, more specifically, to a direct methanol fuel cell system in which active control of the concentration of methanol at a critical point within the cell minimizes crossover of methanol through the cell's membrane.

Background Information

Fuel cells are devices in which an electrochemical reaction is used to generate electricity. A variety of materials may be suitable for use as a fuel, depending upon the materials chosen for the components of the cell. Organic materials, such as methanol or formaldehyde, are attractive choices for fuels due to their high specific energies.

Fuel cell systems may be divided into "reformer based" (*i.e.*, those in which the fuel is processed in some fashion before it is introduced into the cell) or "direct oxidation" in which the fuel is fed directly into the cell without internal processing. Most currently available fuel cell systems are of the reformer-based type and their fuel processing requirement limits their application to relatively large applications relative to a direct oxidation system.

An example of the direct oxidation system is the direct methanol fuel cell system or DMFC. In a DMFC, the electrochemical reaction at the anode is a conversion of methanol and water to CO_2, H^+ and e^-. The hydrogen ions flow through a membrane electrolyte to the cathode, while the free electrons flow through a load which is normally

connected between the anode and cathode providing power to the load. At the cathode, oxygen reacts with hydrogen ions and free electrons to form water.

Conventional DMFCs suffer from a problem which is well known to those skilled in the art: cross-over of methanol from the anode to the cathode through the membrane electrolyte, which causes significant loss in efficiency. Cross-over occurs because of the high solubility of methanol in the membrane electrolyte. In order to minimize cross-over, and thereby minimize the loss of efficiency, the concentration of methanol in the fuel feed stream is kept low (*e.g.,* below 1M) by dilution with water. However, dilution of the methanol introduces other disadvantages: (1) the fuel cell's construction becomes more complicated and costly because of the structures and processes needed to store and manage the water; and (2) the energy per unit volume of the fuel cell, which is a critical factor in terms of the fuel cell's potential commercial applications, is reduced.

SUMMARY OF THE INVENTION

In brief summary, the present invention provides a direct methanol fuel cell system in which, in response to changes in the output power level of the cell, the concentration of methanol supplied to the anode is actively controlled, thereby minimizing methanol cross-over and maintaining efficiency over a wide operating range. Mechanisms for controlling the methanol concentration are preferably constructed using microelectromechanical system (MEMS) fabrication techniques which enable the control mechansim to be readily integrated with the fuel cell's structure.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention description below refers to the accompanying drawings, of which:

Fig. 1 is a block diagram of a direct methanol fuel cell known in the prior art;

Fig. 2 is an exploded view showing details of the internal construction of the fuel cell of Fig. 1;

Fig. 3A is a graph showing the relative concentrations of methanol at various points denoted in Fig. 2;

Fig. 3B is a graph showing the relative concentrations of methanol at various points denoted in Fig. 2 when the fuel cell operates at low and high output power levels;

Fig. 4 is a block diagram of a direct methanol fuel cell system that includes active methanol concentration control constructed in accordance with a preferred embodiment of the present invention;

Fig. 5 is a diagram of a methanol concentration regulator constructed using MEMS fabrication techniques in accordance with one embodiment of the present invention;

Fig. 6 is a diagram of a methanol concentration regulator constructed using MEMS fabrication techniques in accordance with an alternative embodiment of the present invention; and

Fig. 7 is a block diagram of an alternative embodiment of the present invention in which active methanol concentration control is provided without an output power detector.

DETAILED DESCRIPTION OF AN ILLUSTRATIVE EMBODIMENT

Figure 1 shows a conventional direct methanol fuel cell 2 in which a housing 4 encloses a cathode 6, a membrane electrolyte 8 and an anode 10. A load 12 is connected across cathode 6 and anode 10. Methanol and water are introduced into the anode side of housing 4 while oxygen is introduced into the cathode side of the housing. The source of the oxygen is preferably ambient air, but it should be understood that other sources could be used. As a result of the reactions at the anode and cathode, free electrons flow from anode 10 through load 12 to cathode 6, while hydrogen ions flow from anode 10 through membrane electrolyte 8 to cathode 6. So long as the reactions continue, a current is maintained through load 12.

Figure 2 illustrates certain details the internal construction of anode 10, the components of which are shown in exploded form for enhanced clarity. One face of a flow plate 14 is formed as a series of grooves or channels 22a through which a methanol-water mixture (not shown) passes. Flow plate 14 is normally in direct contact with one face of

a gas diffusion layer (GDL) 16. The opposite face of GDL 16 is in direct contact with one face of an electrode 18. Similarly, the opposite face of electrode 18 is in direct contact with one side of membrane electrolyte 8. Four points of interest within anode 10 are denoted by the reference letters A, B, C and D, respectively. Points A, B and C represent interfaces between components and point D represents the cathode side of membrane electrolyte 8.

Referring now to Figures 2 and 3A, one may see how the concentration of methanol varies at points A-D under certain operating conditions. Figure 3A shows methanol concentrations for a typical DMFC operating at a particular output power level. As may be expected, the methanol concentration is highest at point A (*i.e.,* the interface between flow plate 14 and GDL 16) and lowest at point D, with a significant reduction in concentration caused by the electrode 18. While the methanol concentration at point D is low, it is not zero, meaning that some methanol has crossed-over membrance electrolyte 8 and reached the cathode indicating that some methanol has passed through the membrane electrolyte without supplying current to the load.

Referring now to Figure 3B, relative methanol concentrations at points A-D are shown for a fuel cell operating at a low output power level, denoted by reference numeral 24, and at a high power level, denoted by reference numeral 26. In the low power case, the methanol concentration at point C is significantly elevated, indicating excessive methanol cross-over and attendant loss of efficiency. In the high power case, the methanol concentration at point D is quite low, suggesting that an optimal amount or possibly insufficient methanol is being supplied to electrode 18.

Figure 4 shows a DMFC system 28 constructed in accordance a preferred embodiment of the present invention. A housing 30 encloses a cathode 32, membrane electrolyte 34, anode 36, a methanol concentration regulator 38 and an output power detector 40. Detector 40 functions to detect the output power level ofsystem 28 and produce a signal (or other suitable indicator) indicative of changes in that power level to concentration regulator 38. In response to changes in the output power level, concentration regulator 38 functions to increase or decrease the concentration of methanol supplied to anode

36 such that methanol cross-over at membrane electrolyte 34 and the associated loss in efficiency are substantially minimized.

System 28 may be constructed from a variety of commercially-available materials using MEMS fabrication techniques, conventional techniques, or a combination of both.

Figure 5 shows a preferred embodiment of methanol concentration regulator 38 in which the regulator is constructed as an actuator using MEMS fabrication techniques. A closed chamber 44 which is filled with a control liquid 46 may be secured to or formed integrally with flow plate 14 (Fig. 2). A resistive element 48 is disposed within liquid 46 and coupled to power detector 40. As resistive element 48 heats liquid 46, pressure is exerted on flow plate 14, GDL 16 and electrode 18, thereby reducing the flow of methanol to anode 8. Conversely, as element 48 cools, pressure is reduced and the concentration of methanol supplied to anode 8 increases.

Figure 6 shows an alternative embodiment of methanol concentration regulator 38. Here, a microactuator 50, which is preferably constructed using MEMS fabrication techniques, is located either proximate to or possibly within channel 22a of flow plate 14. Thus, as microactuator 50 operates, it functions to apply pressure to or reduced the cross-section of channel 22a, thereby restricting the flow of methanol through it.

Figure 7 shows an alternative embodiment of a DMFC system with active methanol concentration control. Components which are comparable to those shown in Figure 4 are assigned like reference numbers. A methanol concentration regulator 52 is connected in series with load 42. In this embodiment, the output power detector has been eliminated as a discrete component, and its function is effectively integrated into the regulator. Regulator 52 is preferably implemented using a microactuator which may be constructed using a any of a variety of techniques, as described above, with an appropriate choice of material based on the expected power range for a particular application. Regulator 52, responsive to changes in potential at anode 36 or load level, operates to vary the concentration of methanol provided to the anode.

It should be understood by those skilled in the art that various other structures and techniques may be used to implement methanol concentration regulator 38, particularly

those which change the porosity or tortuosity of GDL 16 or electrode 18 or both. Regulator 38 may be mechanically coupled to or integrated with either anode 8 or GDL 16. It should also be understood that the present invention may be used with fuels other than methanol/water mixtures.

What is claimed is:

CLAIMS

1. A direct methanol fuel cell system comprising:

an anode, a cathode, and a membrane electrolyte disposed between the anode and cathode;

a source of air or oxygen coupled to the cathode;

a source of methanol;

a source of water;

a detector for detecting changes in an output power level of said fuel cell; and

a methanol concentration regulator coupled to the methanol source, detector and anode, said regulator responsive to changes in output power level of said cell for varying the concentration of said methanol at said anode such that cross-over of methanol through said membrane electrolyte is substantially minimized over a dynamic operating range.

2. The fuel cell system as in claim 1 wherein said concentration regulator is constructed using microelectromechanical system (MEMS) fabrication techniques.

3. The fuel cell system as in claim 2 wherein said concentration regulator comprises a microactuator mechanically coupled to said anode and operable in response to said detector to increase or decrease a flow of methanol to said anode.

4. The fuel cell system as in claim 3 wherein said microactuator comprises an enclosed chamber mechanically coupled to a flow plate which supplies methanol to said anode, said chamber being filled with a control liquid in which a resistive element is disposed, said resistive element operable in response to said detector to heat said liquid and thereby exert pressure on said flow plate.

5. The fuel cell system as in claim 2 wherein said concentration regulator comprises a microactuator which is integrated with said anode.

6. The fuel cell system as in claim 2 wherein said concentration regulator comprises a microactuator mechanically coupled to a gas diffusion layer and operable in response to said detector to increase or decrease a flow of methanol to said anode.

7. The fuel cell system as in claim 2 wherein said concentration regulator comprises a microactuator integrated with a gas diffusion layer and operable in response to said detector to increase or decrease a flow of methanol to said anode.

8. The fuel cell system as in claim 1 wherein said concentration regulator is constructed using non-MEMS fabrication techniques.

9. The fuel cell system as in claim 1 wherein said concentration regulator is constructed using a combination of MEMS and non-MEMS fabrication techniques.

10. A method of regulating a concentration of methanol in a direct methanol fuel cell system comprising the steps of:

using a detector to sense changes in an output power level of said fuel cell and produce a signal indicative of said changes; and

using said signal to drive a concentration regulator which responsively increases the amount of methanol supplied to said fuel cell's anode when said power level increases, and decreases the amount of methanol supplied to said anode when said power level decreases, thereby minimizing cross-over of methanol through said fuel cell's membrane electrolyte.

11. The method as in claim 10 wherein said concentration regulator is constructed using MEMS fabrication techniques.

12. The method as in claim 11 wherein said concentration regulator comprises a microactuator mechanically coupled to said anode and operable in response to said detector to increase or decrease a flow of methanol to said anode.

13. The method as in claim 12 wherein said microactuator comprises an enclosed chamber mechanically coupled to a flow plate which supplies methanol to said anode, said chamber being filled with a control liquid in which a resistive element is disposed, said resistive element operable in response to said detector to heat said liquid and thereby exert pressure on said flow plate, whereby the flow of methanol to said anode is varied.

14. The method as in claim 11 wherein said concentration regulator comprises a microactuator integrated with said anode.

15. The method as in claim 11 wherein said concentration regulator comprises a microactuator mechanically coupled to a gas diffusion layer and operable in response to said detector to increase or decrease a flow of methanol to said anode.

16. The method as in claim 11 wherein said concentration regulator comprises a microactuator integrated with a gas diffusion layer and operable in response to said detector to increase or decrease a flow of methanol to said anode.

17. The method as in claim 10 wherein said concentration regulator is constructed using non-MEMS fabrication techniques.

18. The method as in claim 10 wherein said concentration regulator is constructed using a combination of MEMS and non-MEMS fabrication techniques.

19. A direct methanol fuel cell system comprising:

an anode, a cathode, and a membrane electrolyte disposed between the anode and cathode;

a source of air or oxygen coupled to the cathode;

a source of methanol;

a source of water; and

a methanol concentration regulator, coupled to the methanol source and anode, responsive to changes in a potential at said anode for varying the concentration of said

methanol at said anode such that cross-over of methanol through said membrane electrolyte is substantially minimized over a dynamic operating range.

20. The fuel cell system as in claim 19 wherein said concentration regulator is constructed using microelectromechanical system (MEMS) fabrication techniques.

21. The fuel cell system as in claim 20 wherein said concentration regulator comprises a microactuator mechanically and electrically coupled to said anode.

22. The fuel cell system as in claim 21 wherein said microactuator comprises an enclosed chamber mechanically coupled to a flow plate which supplies methanol to said anode, said chamber being filled with a control liquid in which a resistive element is disposed, said resistive element operable in response to said detector to heat said liquid and thereby exert pressure on said flow plate.

23. The fuel cell system as in claim 20 wherein said concentration regulator comprises a microactuator which is integrated with said anode.

24. The fuel cell system as in claim 20 wherein said concentration regulator comprises a microactuator mechanically coupled to a gas diffusion layer and operable in response to said detector to increase or decrease a flow of methanol to said anode.

25. The fuel cell system as in claim 20 wherein said concentration regulator comprises a microactuator integrated with a gas diffusion layer and operable in response to said detector to increase or decrease a flow of methanol to said anode.

26. The fuel cell system as in claim 19 wherein said concentration regulator is constructed using non-MEMS fabrication techniques.

27. The fuel cell system as in claim 19 wherein said concentration regulator is constructed using a combination of MEMS and non-MEMS fabrication techniques.

28. A method of regulating a concentration of methanol in a direct methanol fuel cell system comprising the steps of:

sensing changes in potential at an anode or load level of said fuel cell system; and using said sensed changes in potential to drive a concentration regulator which responsively increases the amount of methanol supplied to said fuel cell's anode when said power level increases, and decreases the amount of methanol supplied to said anode when said power level decreases, thereby minimizing cross-over of methanol through said fuel cell's membrane electrolyte.

29. The method as in claim 28 wherein said concentration regulator is constructed using MEMS fabrication techniques.

30. The method as in claim 29 wherein said concentration regulator comprises a microactuator mechanically coupled to said anode and operable in response to said detector to increase or decrease a flow of methanol to said anode.

31. The method as in claim 30 wherein said microactuator comprises an enclosed chamber mechanically coupled to a flow plate which supplies methanol to said anode, said chamber being filled with a control liquid in which a resistive element is disposed, said resistive element operable in response to said detector to heat said liquid and thereby exert pressure on said flow plate, whereby the flow of methanol to said anode is varied.

32. The method as in claim 28 wherein said concentration regulator comprises a microactuator integrated with said anode.

33. The method as in claim 28 wherein said concentration regulator comprises a microactuator mechanically coupled to a gas diffusion layer and operable in response to said detector to increase or decrease a flow of methanol to said anode.

34. The method as in claim 28 wherein said concentration regulator comprises a microactuator integrated with a gas diffusion layer and operable in response to said detector to increase or decrease a flow of methanol to said anode.

35. The method as in claim 28 wherein said concentration regulator is constructed using non-MEMS fabrication techniques.

36. The method as in claim 28 wherein said concentration regulator is constructed using a combination of MEMS and non-MEMS fabrication techniques.

ABSTRACT OF THE DISCLOSURE

A direct methanol fuel cell (DMFC) system in which, in response to changes in the output power level of the cell, the concentration of methanol supplied to the anode is actively regulated. As a result, cross-over of methanol through the cell's membrane electrolyte is minimized, and operating efficiency is maintained over a wide dynamic range of output power levels.

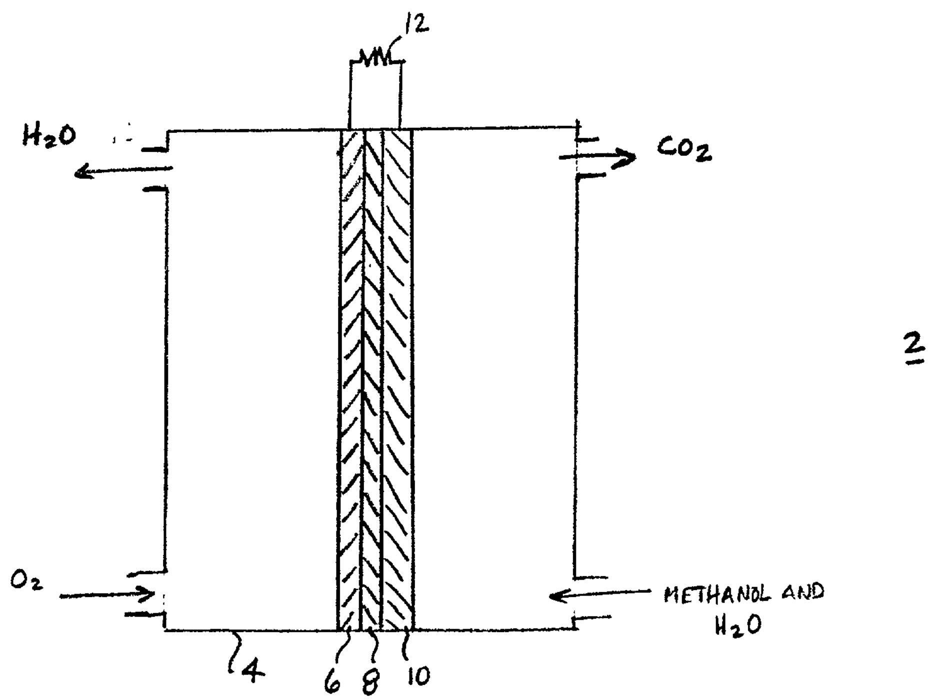

FIGURE 1

(PRIOR ART)

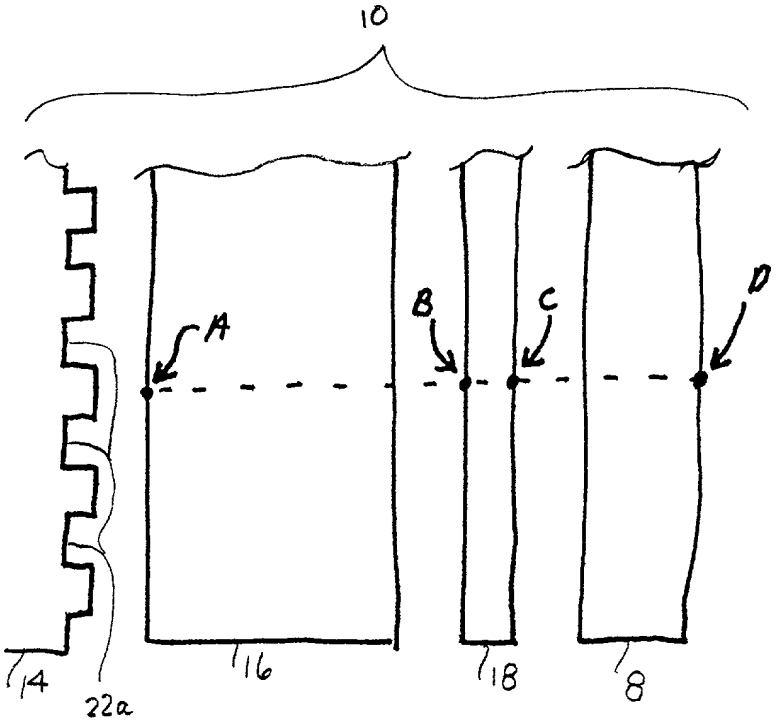

FIGURE 2

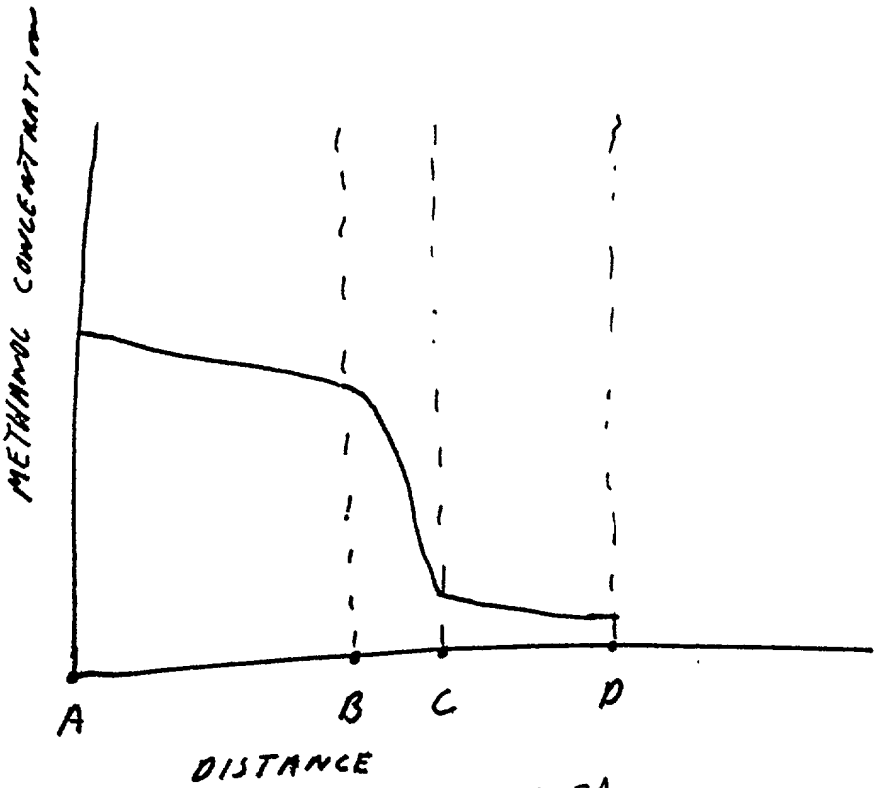

FIGURE 3A

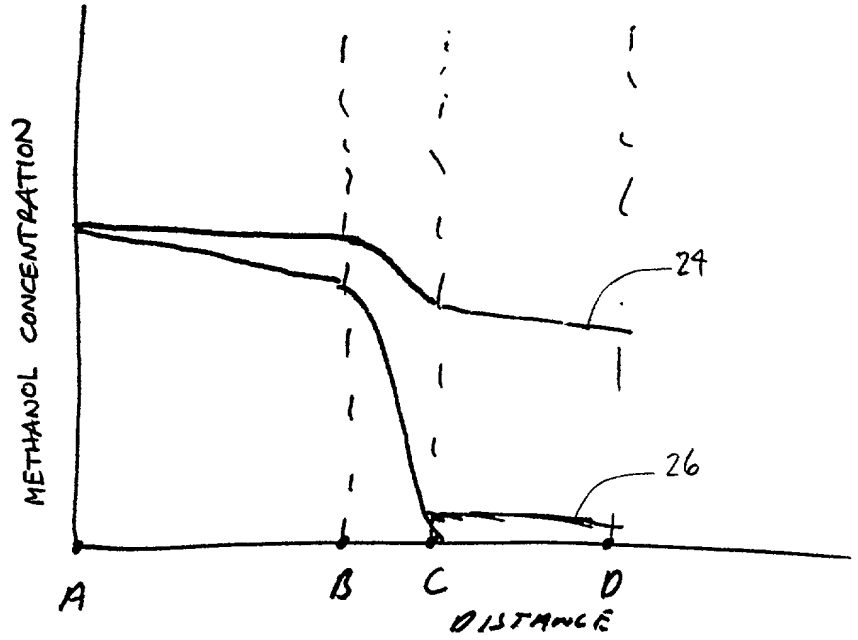

FIGURE 3B

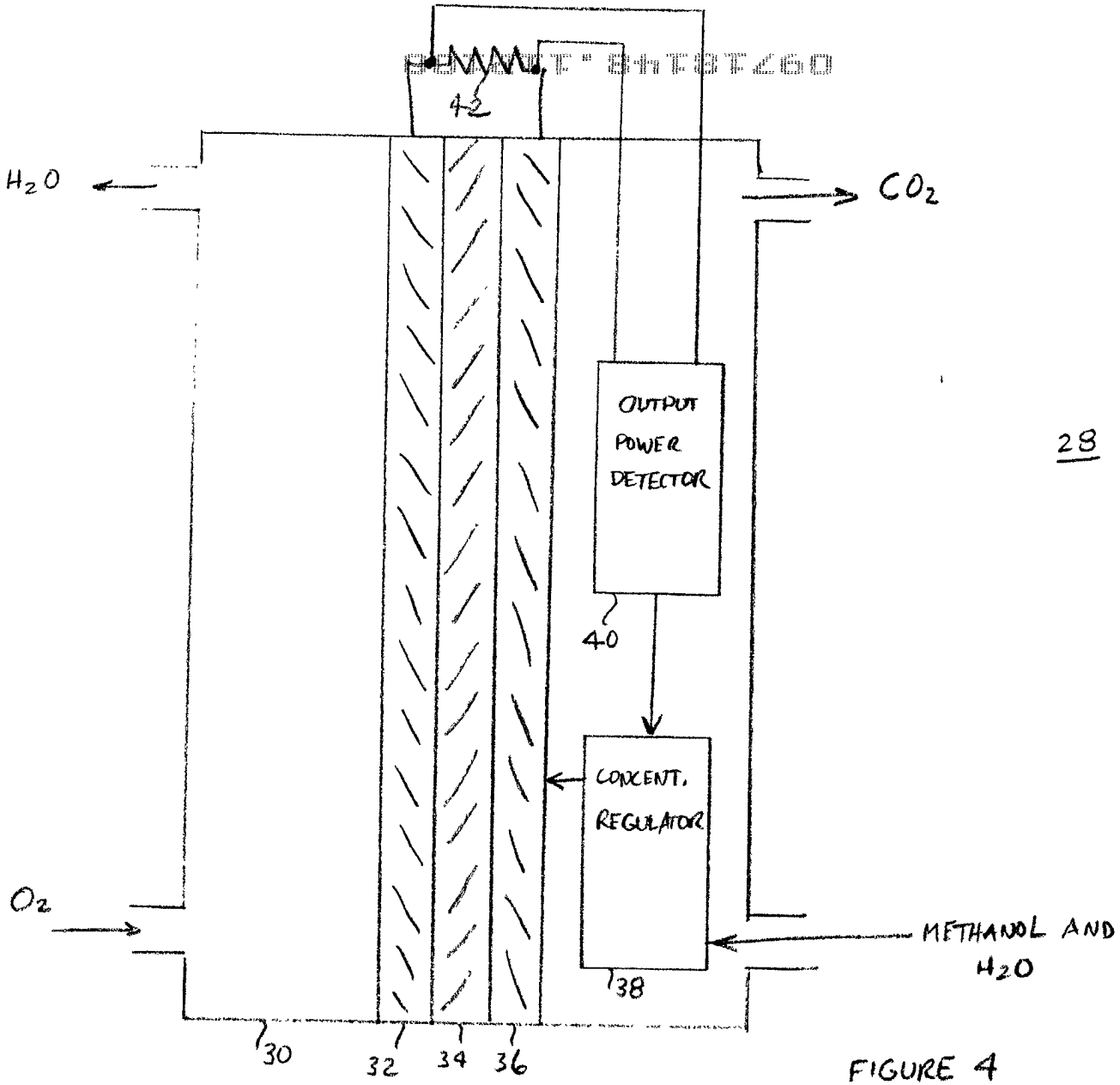
42
H_2O
CO_2
OUTPUT POWER DETECTOR
40
28
CONCENT. REGULATOR
38
O_2
METHANOL AND H_2O
30
32
34
36

FIGURE 4

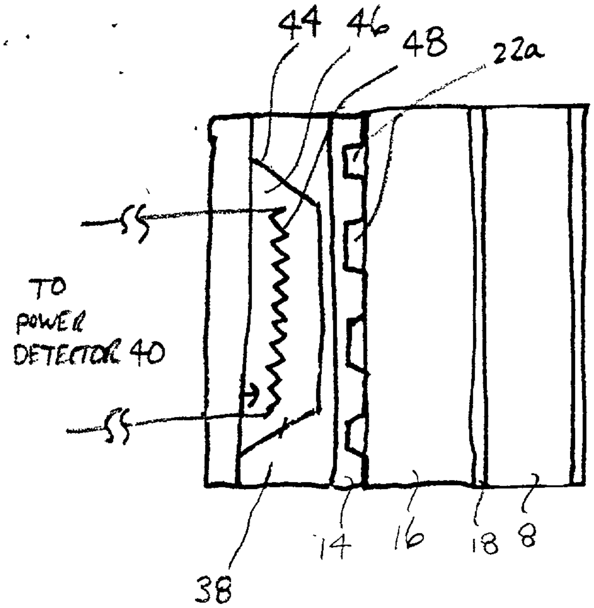

FIGURE 5

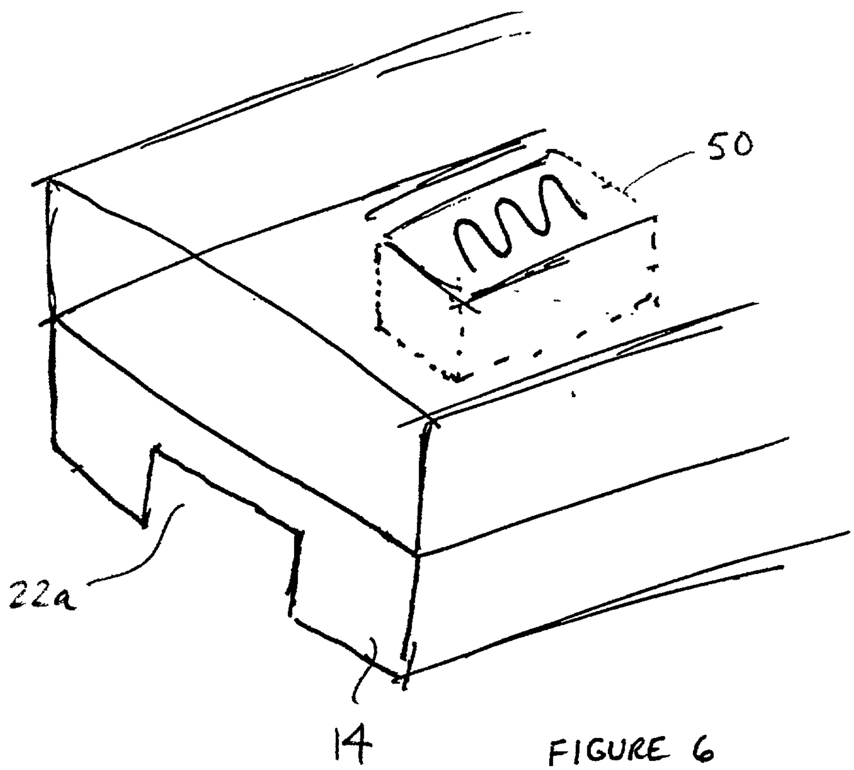

FIGURE 6

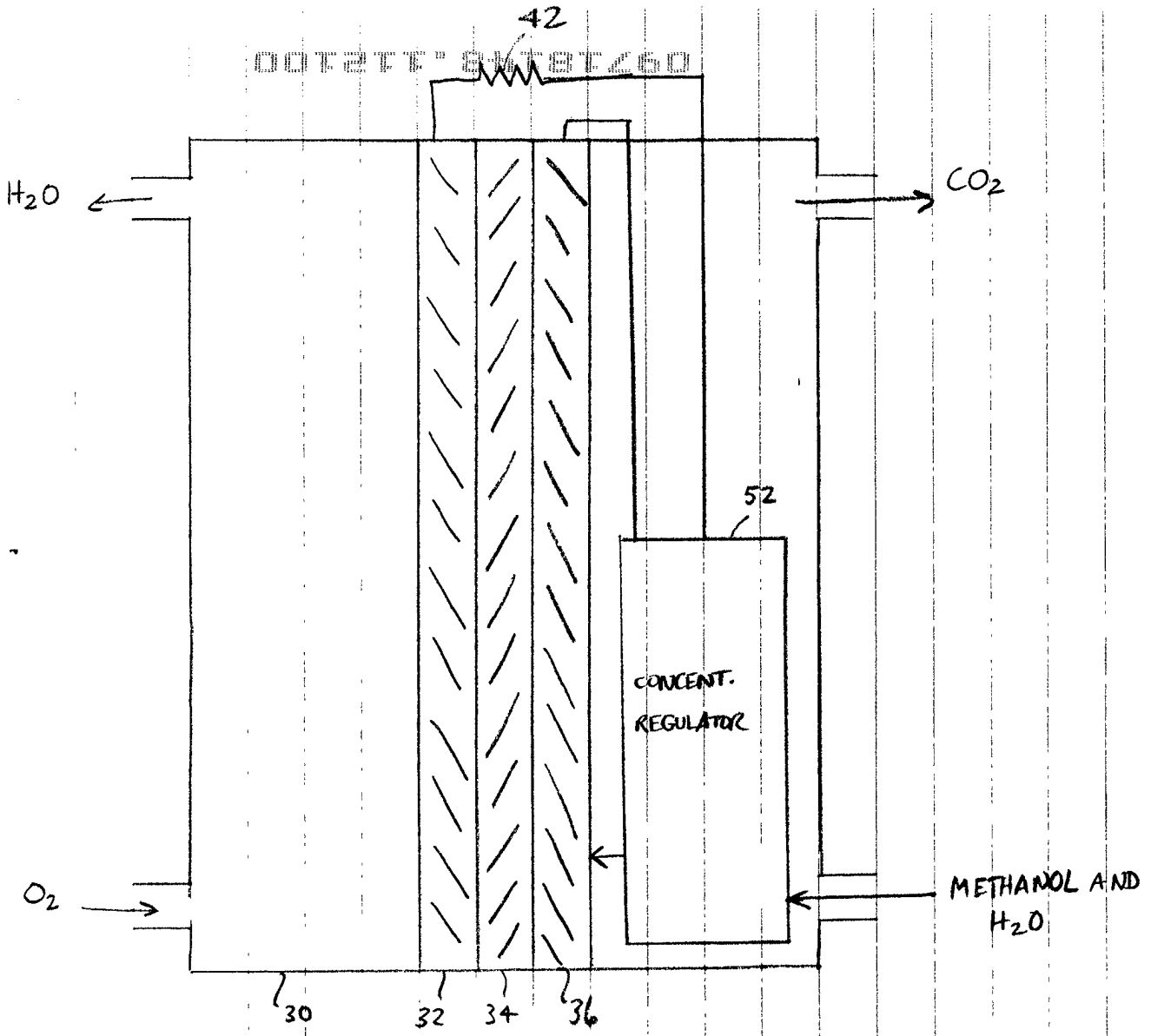
42
H_2O
CO_2
52
CONCENT.
REGULATOR
O_2
METHANOL AND
H_2O
30
32
34
36

FIGURE 7

PATENTS
107044-0002

DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

As a below-named inventor, I hereby declare that:

My residence, post-office address, and citizenship are as stated below next to my name.

I believe I am an original, first, and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled FUEL CELL SYSTEM WITH ACTIVE METHANOL CONCENTRATION CONTROL, the specification of which is attached hereto and identified by Cesari and McKenna File No. 107044-0002.

I hereby state that I have reviewed and understand the contents of the above-identified application specification, including the claims, as amended by any amendment specifically referred to herein.

I acknowledge the duty to disclose all information known to me that is material to patentability in accordance with Title 37, Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code §119(a)-(d) of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate filed by me on the same subject matter having a filing date before that of the application on which priority is claimed:

None

I hereby claim the benefit under Title 35, United States Code §119(e) of the following U.S. provisional application:

None

I hereby claim the benefit under Title 35, United States Code §120, of the United States Application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United State Code, §112, I acknowledge the duty to disclose all information that is material to patentability in accordance with Title 37, Code of Federal Regulations, §1.56, and which became available to me between the filing date of the prior application and the national or PCT international filing date of this application:

None

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the

like so made are punishable by fine or imprisonment or both under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

I hereby appoint Michael E. Attaya, Reg. No. 31,731; Charles J. Barbas, Reg. No. 32,959; Joseph H. Born, Reg. No. 28,283; John L. Capone, Reg. No. 41,656; Robert A. Cesari, Reg. No. 18,381; Brian C. Dauphin, Reg. No. 40,983; Howard S. Fuhrman, Reg. No. 33,175; Christopher K. Gagne, Reg. No. 36,142; A. Sidney Johnston, Reg. No. 29,548; William A. Loginov, Reg. No. 34,863; John F. McKenna, Reg. No. 20,912; Rama B. Nath, Reg. No. 27,072; Martin J. O'Donnell, Reg. No. 24,204; Thomas C. O'Konski, Reg. No. 26,320; Edwin H. Paul, Reg. No. 31,405; Michael R. Reinemann, Reg. No. 38,280; Rita M. Rooney, Reg. No. 30,585; Heather B. Shapiro, Reg. No. 41,305; Patricia A. Sheehan, Reg. No. 32,301; and Joseph Stecewycz, Reg. No. 34,442, Cesari and McKenna, LLP, 88 Black Falcon Avenue, Boston, Mass. 02210, jointly, and each of them severally, my attorneys and attorney, with full power of substitution, delegation and revocation, to prosecute this application, to make alterations and amendments therein, to receive the patent and to transact all business in the Patent and Trademark Office connected therewith. Please direct all telephone calls to Michael E. Attaya at (617) 951-2500. Please address all correspondence to Michael E. Attaya.

William P. Acker — Date: NOV 20, 2000

Residence: 5 Willow Spring Drive, Rexford, NY 12148

Citizenship: United States of America

Post Office Address: Same as above

PATENTS
107044-0002

George C. McNamee — 11/20/00 Date

Residence: 9 Loudon Heights South
Loudonville, NY 12211

Citizenship: United States of America

Post Office Address: Same as above

William W. Dailey — 11/20/00 Date

Residence: 2 Primrose Lane
Loudonville, NY 12211

Citizenship: United States of America

Post Office Address: Same as above